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## PRESERVATION OF THE PHOSPHATES AND THE CONSERVATION OF THE SOIL

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In a very impressive paper upon *The Natural Wealth of the Land and Its Conservation*, given at the White House at the Conservation Conference, May 13, 1908, Mr. James J. Hill gave a comprehensive picture of the importance of our soil resources, and a severe arraignment of our want of foresight and reckless extravagance which unless checked in the near future threatens to impoverish our nation in its most fundamental asset.

There can be no question as to the correctness of Mr. Hill's position as to the profound importance of the conservation of the soil. Food and clothing, products of the soil, we must have. All of our other wants are subordinate to these.

Mr. Hill says: "Our agricultural lands have been abused in two principal ways: first, by single cropping, and, second, by neglecting fertilization."

In reference to these abuses he says: "The two remedies are as well ascertained as is the evil. Rotation of crops and the use of fertilizers act as tonics upon the soil. We might expand our resources and add billions of dollars to our national wealth by conserving soil resources instead of exhausting them, as we have the forests and the contents of the mines."

Mr. Hill did not mention the first cause for the depletion of the soil, that of soil wastage through erosion; but this aspect of the subject was handled by Professor Chamberlain at the conference. Also McGee and others have painted woeful pictures of the frightful loss of soil by erosion, which has removed the upper part of the soil for a large part of many states and which has even converted extensive areas into bad lands. Therefore, I shall not discuss the dumping of the soil into the sea by the rivers in incredible quantities through cultivation without reference to the conditions necessary to prevent erosion. But it is plain that we must not permit soil erosion to take place more rapidly than the soil is manufactured by the

processes of nature. To do so will be ultimately to destroy our soils. If nature manufactures the soil at the rate of one inch in a century, then the erosion must not exceed one inch in one century.

Neither shall I more than mention the question of rotation. One of the chief purposes of rotation is obvious. A crop of one kind draws heavily upon certain elements of the soil. Another does not demand so much of this element. Therefore, it is plain that by rotation of crops the elements of fertility may be drawn upon more slowly and proportionally, and thus, through proper procedure, enable the farmer to retain in the soil an adequate supply of each of the important elements.

The subject to which I wish especially to ask your attention is that of fertilizers. Mr. Hill says: "Fertilizers act as tonics upon the soil." This naturally raises the question as to our resources in these materials. The three plant foods which are most likely to be present in insufficient quantity in the soil and which are most expensive to supply are nitrogen, potassium and phosphorus.

Fortunately, in the atmosphere is an inexhaustible quantity of nitrogen. The problem is to get this free nitrogen into a form in which it can be used by plants. Until comparatively recently this was regarded as almost hopeless, but the discoveries of recent years show that there are two ways in which the nitrogen of the air may be fixed. The leguminous plants, by the aid of bacteria, combine nitrogen in large quantities with other elements and add it to the soil in a form that may be used by non-leguminous plants. By electrical methods, also, nitrogen may be directly combined with other elements. Thus, so far as this element is concerned, the problem is solved. By applying the knowledge which science has furnished us, the soil need never lack the nitrogenous element of plant food.

In the original igneous rocks the average percentage of potassium is about two and one-half. However, there are inexhaustible masses of rock in which the percentage is about three times this average. Therefore the total amount of this element is practically unlimited. By nature's processes potassium has been extensively abstracted from the original rocks and has been concentrated, so that in various parts of the continents there are large quantities of this element in a readily soluble form which are available for fertilizing the soils deficient in it. Even if in the future these segregated and soluble deposits of potassium are exhausted we may

still use the original rocks, which are more than ordinarily rich in this element, as a source from which more concentrated material may be manufactured, or the very finely pulverized rocks may be used directly as a fertilizer.

The only remaining element about which we need concern ourselves is phosphorus. This is the element which, so far as we can see at the present time, presents a profoundly serious problem in maintaining the fertility of the soil. Clarke,<sup>1</sup> in his *Data of Geo-Chemistry*, estimates that the crust of the earth contains only .11 of one per cent. of phosphorus, or about .25 of one per cent. of phosphoric oxide. As we have just seen, the average rocks contain twenty times as much potassium. Therefore, looking toward the distant future, if we consider ratios, we may unhesitatingly assert that the problem of maintaining the fertility of the soil in phosphorus will be twenty times as difficult as for potassium; but this ratio by no means measures the real difference, for when a deposit contains a moderate percentage of a substance it may be possible to utilize it commercially; whereas, if the percentage falls below this amount, it is without value.

It is one of the great laws of nature that, under favorable conditions, the forces and agents of rock alteration tend to segregate locally each of the elements. To such processes of segregation are due the available metallic ores, since the average amounts of the valuable materials in the rocks are far below those in the workable ore deposits.

The segregative processes of nature have fortunately concentrated phosphorus in various ways, and these deposits are the chief source of supply of our phosphates.

The earliest phosphatic fertilizer to be used was guano, mainly derived from the islands off the west coast of South America. If the segregation of phosphorus in guano were fully described it would be appreciated how slow and intricate is the process of concentration of a rare element. The story would involve, first, the solution of the widely disseminated phosphorus from the original rocks, its segregation through complex processes in the small plants and animals that become the food of fishes, which in turn become the food of the sea birds. The dry excrement of the sea bird constitutes the guano. Much of the guano contains twenty-five to forty per cent.

<sup>1</sup>Bulletin, U. S. Geol. Survey, No. 330.

phosphoric oxide. Thus nature's processes of segregation have multiplied the amount of phosphorus in the original rock by from one hundred to more than one hundred fifty fold.

Carcilas de la Vega,<sup>2</sup> in the sixteenth century, gave "a very interesting account of the manner in which the birds producing the guano were protected by the laws of the Incas, by which it was made a crime, punishable by death, to kill the sea fowl, gather their eggs, or even to visit the islands during the breeding season."

A recent report by Robert Coker<sup>3</sup> to the government of Peru upon the future of the guano industry and the guano-producing birds tells of "the robbery of eggs on a large scale in past years, the destruction of young and old birds, and the disturbance of the birds in their nesting grounds by the extraction of guano." He says an inevitable result "has been a great diminution in number." Mr. Coker's report pleads for regulations to increase the number of birds and thus to maintain perpetually a large supply of guano. With reference to the most precious of the fertilizers this twentieth century presents an ignominious and startling contrast with an ancient civilization.

In considering the ill treatment of the guano-producing birds it is difficult for one to retain composure and speak with moderation of the odious combination of human greed and brutality exhibited by this case of exploitation of a natural resource, in complete ignorance and absolute disregard of its effect upon the future of our race. The phrase "killing the goose that laid the golden egg" was never more applicable.

Long before man existed on the earth the ancient phosphatic segregations of birds and other animals formed upon an extensive scale were buried among the sediments and have been partially preserved in the rocks. These deposits constitute the chief sources of our mineral phosphates. Until recently the most extensive known deposits were those of Florida, South Carolina and Tennessee. In the year 1907 in these states almost exclusively, according to Mr. F. B. Van Horn, 2,265,343 tons of phosphate rock were produced. While the amount exploited is now large, none of the scientists who have examined these deposits hold out any hope that their extent is so great that they can be relied upon as a source of phosphate fer-

<sup>2</sup>Johnson's Universal Ency., Vol. 4, p. 52.

<sup>3</sup>Science, July 10, 1908, p. 60.

tilizer for more than a very brief period. Van Horn estimates that the high-grade rock will be exhausted at the present rate of mining in about twenty-five years.

Aside from these southern phosphates, we gain small amounts of phosphorus as by-products in the concentration of the magnetite iron ores of the east and from the slag of steel manufactured by the basic and open-hearth processes. These operations segregate the small amounts of phosphorus in the iron ores so as to give the by-products a marketable value. But from these sources we cannot expect more than an insignificant fraction of the phosphatic fertilizer required by the agricultural interests of the United States.

Fortunately, recent investigations<sup>4</sup> by the officers of the United States Geological Survey have shown that in Utah, Wyoming and Idaho are phosphatic deposits, regarded by Weeks and Ferrier, the reporting officers, as more extensive than have as yet been known to exist in this country.

At a number of places a rich phosphate bed five or six feet thick has been found, and above this bed are from fifty to one hundred feet containing thin layers of phosphate. While this western supply of phosphates is doubtless large, the explorations have been far too scanty to warrant any quantitative statement, and even under the most favorable hypothesis of continuity throughout the formation in which they exist, and of this they are sure to fall far short, they would still not be adequate to meet the needs of the nation through the centuries to come.

As yet the phosphate deposits of Utah, Wyoming and Idaho remain practically untouched. They are one of the most precious of the natural resources of the nation, having a value inestimably greater than might be supposed from the present marketable value of phosphate rock.

In Canada there are areas of crystalline rocks in which phosphates have been locally segregated. Also in other countries there are phosphatic deposits. But upon these foreign supplies we can in no way depend. The demand for phosphatic fertilizers by the agricultural interests of each country is sure to be so great that it may be confidently predicted that in the near future no nation will per-

<sup>4</sup>Investigations relating to phosphates and phosphorus in 1907, F. B. Weeks and W. F. Ferrier, Bulletin No. 315, U. S. Geol. Survey.

Investigations relating to phosphates in 1907, F. B. Weeks, Bulletin No. 340, U. S. Geol. Survey.

mit the exportation of phosphates, with the possible exception of countries like Peru, where large quantities are being produced each year through bird life.

The general and alarming decrease in the crop yield per acre in various states, so well described by Mr. James J. Hill, is largely due to the depletion of the soil in phosphorus. This is clearly shown by the investigations of the various agricultural stations. In order that the present relatively small productivity of the southern states may continue it requires the use each year of many thousands of tons of phosphate fertilizer. Even the soils of the rich central states, the garden of the United States, are deficient in this important element. The experiments of the Ohio station show that the use of phosphatic fertilizer largely increases the crop yield and is a source of great profit to those using it. Indeed, the work of this station upon different fertilizers showed that "for the soils tested in their experiments phosphorus was the controlling element in producing an increase in the cereal crop."<sup>5</sup>

Even for Illinois, correctly regarded as one of the most fertile states in the union, an extensive investigation by the state experiment station shows that "none of the soils are very rich in phosphorus, while many of them are considerably below the standard fertile soil, and two or three soils of large area are markedly deficient in that element, particularly the large areas of so-called white clay soil."<sup>6</sup>

These studies in Ohio and Illinois are confirmed by quantitative studies in Wisconsin. Whitson finds as a result of the average of nine typical tests that "the surface eight inches of virgin soil contains 2877 pounds of phosphoric oxide per acre, while that of the cropped fields contains but 1813 pounds, an average loss per acre on these cropped fields of 1064 pounds, or thirty-six per cent. of its original content. The average period of cropping for these fields has been 54.7 years." In other words, during the past half-century in Wisconsin one-third of the original phosphorus of the soil has been lost in the cropped fields. What has been proved for Ohio, Illinois and Wisconsin and other states where tests have been made is unquestionably true for the other states in the country which have been settled for some time.

<sup>5</sup>Ohio State Agricultural College, Bulletins Nos. 141, 182.

<sup>6</sup>Illinois Agricultural Experiment Station, Bulletin No. 68.

In what condition will the soil of the United States be as to phosphorus content fifty years hence if this process of depletion be allowed to continue unchecked?

The phosphorus which is taken out of the soil by cropping could be largely returned to it if all the manure of the domestic animals were saved and utilized. The experiments of the Ohio station show that the manure from domestic animals retains more than three-fourths of the phosphorus contained in the food and bedding, a large part of the remaining one-fourth being built up in the systems of the animals. Thus, if the excrement from all domestic animals, both in town and country, were returned to the soil more than three-fourths of the phosphorus would go back to it. But as yet our agricultural population is most delinquent as to the manner in which they handle the feces and urine of the domestic animals. Whitson estimates that the loss of phosphates in manure as a result of waste and wash amounts in Wisconsin to fifteen per cent., and this is probably less rather than more than the average for the country as a whole. The agricultural colleges and experiment stations, through teaching the students and through extension, have a heavy responsibility in driving home to the farmer the necessity of stopping the irreparable waste of the valuable fertilizers and especially the phosphates.

The phosphates which pass into the bones of domestic animals, so far as they are killed in the great abattoirs, become valuable by-products, which are sold to the farmer, and thus are returned to the soil.

There remains only to consider man as a source of phosphates. In this country there has been as yet practically no attempt to return the excrement of man to the soil. This is true of both country and city. In the country the solution of the problem of handling the human excrement so as to use it as a fertilizer is comparatively easy, but the education of the farmer so that he will apply the solution will prove a difficult task, which must be taken up at many thousands of centers. At the present time, through our concentrations into cities and towns, and the running of sewage into the streams, a large proportion of the human excrement, as well as that of animals, rich in phosphorus, goes to the rivers and thence to the sea, so that there is vast and unnecessary loss of the phosphates. Whitson estimates that the loss in the cities due to man alone is the equivalent of two or three pounds of phosphoric oxide per acre for the entire cropped



region of the United States. Suppose this loss to be two pounds, this is 1/1000 of a ton, which amounts for the 400,000,000 acres to 400,000 tons of phosphoric oxide, or equivalent to 1,200,000 tons of phosphate rock. The method of sewage disposal now in vogue should be wholly abandoned and the phosphates of the sewage returned to the soil. The saved phosphates alone would more than justify the cost, without taking into account the enormous advantages of freeing the living water from pollution.

The wide disbursal of vast quantities of phosphorus which it took the process of nature an indefinite period to segregate, must cease. The loss is irreparable. In this matter we may well turn to China and Japan for guidance. The evidence is clear that the people of these ancient nations, which have had a dense population for many centuries and have preserved the fertility of their soils, have carefully saved and utilized animal and human excrement.

At the present time there is need for much more phosphate rock than we now quarry to neutralize the annual loss of the soil due to the waste of animal and human excrement. Whitson's investigations show the loss of phosphoric oxide in the fields tested in Wisconsin to be annually about twenty pounds per acre. To be conservative, let us suppose that the average loss for the United States is but one-half of this amount. For 400,000,000 acres, less than the total of the cropped land, this would represent an annual loss of 2,000,000 tons of phosphoric oxide; but since the phosphate mined is only about one-third phosphoric oxide, to supply this amount would require 6,000,000 tons of rock.

If we suppose the total accumulated loss of the soils of the United States from natural conditions due to cropping is one-half that found by Whitson in the fields tested in Wisconsin, the amount would be a quarter of a ton per acre, and for 400,000,000 acres, 100,000,000 tons of phosphoric oxide, which is the equivalent of 300,000,000 tons of phosphate rock. Thus, to make good the phosphorus already lost to the soil in the United States by reckless disregard of the future, would require the present output of our mines for more than a century, even if at once it were possible to prevent further depletion of the soil, and no more of our phosphate rock were required to neutralize the current waste.

In Sweden, the government decides as to whether it is wise to allow iron ore to be exported, and limits the amount which may

be sent out of that country each year. In this country we have allowed to pass unnoticed the establishment of the Franco-American Consolidated Phosphate Company, the majority of the stock of which is owned abroad, and which has already acquired extensive holdings of phosphate lands in Tennessee. In 1907, even before the formation of this company, forty per cent. of the phosphate rock mined was exported, and doubtless the organization of this company will increase the proportion. This state of affairs could exist in no other civilized nation. Indeed, by the statesmen of foreign civilized nations exportation of phosphates would be regarded as unthinkable folly. If the statements presented in this paper are even approximately true, and it is believed that every one of them is justified, there should be a law which prohibits absolutely the exportation of a single pound of phosphate rock. It is not certain that the total supply of phosphate rock in the southern and western states together is sufficient to restore the lands of the United States to their original fertility in phosphorus, to say nothing of providing for the great annual loss through our present methods of handling fertilizers produced on the farms, and disposal of sewage.

During the summer of 1908 the attention of President Roosevelt was called to the facts presented in this paper, and it was urged that the western phosphate lands now owned by the Government should be withdrawn from private entry until such time as legislation could be secured to permit their exploitation upon a lease system, containing a clause preventing the exportation of the phosphates. Later the matter was again presented to the President and to James R. Garfield, then Secretary of the Interior. Both the President and Mr. Garfield instantly appreciated the fundamental importance of the matter, and on December 9, 1908, the phosphate lands of the west were formally withdrawn from private entry, thus retaining these deposits of fundamental importance to the future of the nation as its property.

It now remains for Congress to do its part in enacting appropriate legislation so that the fruits of the acts of the President and the Secretary may be permanently secured to the people. If no other result than this had come from the movement inaugurated by President Roosevelt to conserve the natural resources of the nation, all that has been done in this connection would have been justified many fold.

Hopkins<sup>7</sup> well says: "If he who makes two blades of grass grow where but one grew before is a public benefactor, then he who reduces the fertility of the soil so that but one ear of corn grows where two grew before is a public curse."

That nation only can reach the highest intellectual and spiritual level that is well nourished. Nourishment requires food. Food depends upon the necessary elements to feed the plants in the soil. Of these we can see no future danger so far as nitrogen and potassium are concerned, but because phosphorus is relatively so rare an element, because it has been segregated by the processes of nature in so limited an amount, since it is so essential to the growth of both plants and animals, it is clear that we should exercise the utmost foresight in conserving the natural concentrations of phosphorus and retaining that still in the soil.

Already we find our most basal resource, the soil, depleted by erosion, depleted by single cropping, and depleted most seriously of all by loss of phosphates. It is a fundamental duty of this generation to transmit to the succeeding generation the soil of the country undiminished in its productivity, for all other resources are as naught if the soil fails us. The damage that we have already done to this resource which should remain perpetually undiminished is inestimable and largely irreparable. The question now confronts us, shall we continue our present course of reckless impoverishment of the soil, taking no thought of the morrow?

We should work with the agents of the earth rather than reverse their work, as we have been doing since American settlement began.

How long shall this nation endure? Or more exactly, how long shall human beings occupy this land. As yet the human race is in its infancy. History goes back a few thousand years. The human race may have existed some score of thousands or even some hundreds of thousands of years; but while in years there is a considerable past history of the race, it is only within the past two centuries that the lands of the country have been subject to agriculture upon an extensive scale, and the main drafts upon the soil have been within the past century.

How long shall our people endure? We should think, not of a hundred years, nor of a thousand years, but of hundreds of thou-

<sup>7</sup>Illinois Agricultural Experiment Station, Bulletin No. 68.

sands, or of millions of years of development of the human race. There is no reason, from a geological point of view, why human beings may not live upon this earth for millions of years to come, perhaps many millions of years, and so far as we are concerned, such periods as these are practically infinite.

These considerations impose upon us as our most fundamental duty the transmission of the heritage of our natural resources to our descendants as little diminished as possible. This is an individual responsibility, as well as a state and national responsibility. There is a strongly developed opinion at the present time that the owners of great wealth and especially those who control great natural resources should act as trustees for the nation. This is easy to see; but a man who owns a farm is equally a trustee to the nation for this property. If, at the end of his life, the farm goes to his son depleted in richness, he is as truly faithless to his trust as are the great interests that think only of present gain and wastefully exploit the natural resources of the country. Each in proportion to his own responsibility is a traitor to the nation. At the present time, fortunately, this sense of stewardship is gaining possession of some of those who control the great resources of the nation. As yet there is scarcely a glimmering of responsibility in the case of the smaller holder of natural resources. But the future of the nation is only safe when small and large holder alike, from the man who owns forty acres of land to the small group of men who control the anthracite of the nation, shall administer their trust primarily for the benefit of succeeding generations rather than for themselves.

I do not hesitate to assert that from the point of view of our descendants, this question of conservation of our natural resources is more important than any political or social question, indeed, more important than all political or social questions, upon the solution of which we are now engaged. Not only is it more important, but it is pressing, for already our unnecessary losses in reference to the soil are irremediable, and the situation is growing steadily worse.

It is necessary that a great campaign of education be inaugurated at once with reference to the conservation of the soil, just as there has been a campaign of education with reference to the conservation of the forests. The task is an enormous one, indeed vastly greater than that carried on with reference to our other resources, because of the fact that the land holdings are so subdivided; but the cam-

paign of education must be carried on, and as a part of it the laws must be developed until we reach the situation where no man dares so to handle his land as to decrease its fertility. If present methods are allowed to continue, it is certain that this country will be able to support only a sparse population. Only by the conservation of our soil undiminished in its fertility can we hope to be able to provide for the hundreds of millions of people who in the near future in the United States will be demanding food and clothing. The conservation of the soil is the conservation of the basal asset of the nation.